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Projected Changes in Rainfall and Temperature in Southern Sri Lanka Using CMIP6 Models under Various Shared Socioeconomic Pathways for Different Climatic Periods

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Abstract

Climate change constitutes a formidable obstacle to pursuing sustainable development across numerous nations. Sri Lanka is facing significant challenges due to climate change. In response, individuals and organizations are mobilizing efforts to address this pressing issue. This study centers on the anticipated alterations in precipitation and temperature within the Southern Province of Sri Lanka, utilizing models from the Coupled Model Intercomparison Project Phase 6 (CMIP6). This research employed downscaled data from the grid, specifically representing the Southern Province. Various models were leveraged to analyze this downscaled data, further enabling the projection of future climate changes under diverse scenarios and temporal frameworks. Validation was carried out by juxtaposing model-simulated historical climate data with actual observed records, a process that is essential for ensuring the study's data reliability. Downscaled data were analyzed using the trend pattern for different models. The multimodel ensembles revealed distinct patterns of temperature and precipitation increase across different Shared Socioeconomic Pathways (SSPs) 4.5 and 8.5 in the Southern Province from 2020 to 2100. Under the SSP2-4.5 scenario, the projected temperature is anticipated to rise by 1.18°C, with a corresponding increase in rainfall of 122.76 mm. In the SSP5-8.5 scenario, the temperature is projected to escalate by 1.91°C, along with a 148.47 mm rise in precipitation. Although these projections are grounded in model simulations, the actual consequences will be contingent upon future greenhouse gas emissions. The Southern Province may witness significant changes in both the intensity and duration of temperature and rainfall. Policymakers and communities should integrate these climate projections into their development and implementation of climate change adaptation strategies.

Keywords: ensemble, projection, shared socioeconomic pathways, temperature

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INTRODUCTION

Climate change represents an urgent global dilemma that has inflicted widespread devastation. Since the dawn of this century, it has been the root cause of numerous crises, manifesting in shifts in global temperatures and contributing to the phenomenon of global warming (Fernández-Nóvoa et al., 2024). Research into forthcoming climate alterations has risen to a paramount global priority. By comprehending these impending changes, we can take proactive measures to mitigate or adapt to them (Arfasa et al., 2024b). In recognition of this urgency, many nations are undertaking rigorous research into future climate dynamics and implementing active responses (Munawar et al., 2022). Immediate and decisive action to address the climate crisis can only be realized through substantial public endorsement of transformative lifestyle changes. Perspectives that aim to postpone climate action and rationalize insufficient mitigation measures, frequently referred to as 'discourses of delay,' are pervasive in the political and media discourse surrounding climate change. In this report, we present the outcomes of innovative public deliberation and visioning workshops held throughout the UK in 2020 and 2021, aimed at exploring envisioned futures aligned with a 1.5 °C trajectory (Cherry et al., 2024). Despite the ambitions of the Paris Agreement to confine global warming to well below 2°C, the prevailing national commitments to curtail emissions, if fulfilled, are anticipated to engender a minimum increase of 3 °C in global temperatures. Some economists employing cost-benefit climate-economy models have previously asserted that a 3 °C rise may embody optimal climate policy (Nordhaus,2018).

Climate change has unequivocally emerged as a formidable threat to the world economy, its ramifications permeating both primary and secondary sectors of economic development (Radhakrishnan & Sujatha, 2024). It is intricately linked to extreme weather occurrences, such as heatwaves, cold snaps, droughts, cyclones, floods, and extreme precipitation events (Intergovernmental Panel on Climate Change [IPCC], 2023). Numerous regions across Asia, including South Asian countries, are currently grappling with the detrimental impacts of climate change (Asian Development Bank [ADB], 2010). The innovative scenario framework for climate change research envisions the integration of projected pathways of future radiative forcing and their corresponding climatic alterations with diverse trajectories of socioeconomic development, thereby facilitating comprehensive investigations into the impacts of climate change, adaptation strategies, and mitigation efforts(O'Neill et al., 2014). This phenomenon has evolved into one of the most pressing challenges facing the global community today, serving as the fundamental cause of an array of issues, ranging from a worldwide food crisis and environmental degradation to an increase in the frequency of natural disasters(McKay et al., 2022). The repercussions of climate change are widespread, transcending regional and national boundaries, thereby affecting all facets of society (Adams & Heidarzadeh, 2022).

Sri Lanka, as an island nation, has encountered a multitude of climate-related challenges that necessitate attention, highlighting the urgent need for both global and national policy reforms (Karunarathne, 2023). In Sri Lanka, climate change is increasingly recognized as a critical issue, particularly due to its adverse effects on water resources (Surasinghe et al., 2020). The nation's high temperatures, unique and intricate hydrological systems, and vulnerability to extreme climatic events render it particularly susceptible to climate change (Dasandara et al., 2021). The primary determinant of temperature fluctuations within Sri Lanka is altitude, with considerably lower temperatures recorded in the south-central mountain ranges. Precipitation in Sri Lanka is categorized into three distinct zones: the dry zone, the wet zone, and the intermediate zone. The wet zone, located in the southwest, receives an average annual rainfall exceeding 2,500 mm, significantly influenced by the southwest monsoon (Gunaratne et al., 2021). The Sri Lankan government is confronting substantial challenges in alleviating the impacts of climate change on the nation’s water resources. Climate change is adversely affecting all sectors in Sri Lanka (Dananjaya et al., 2022).

The geographical attributes of the southern province are situated at 6°10' North latitude and 80°45' East longitude. This province is bordered by the Sabaragamuwa and Uva provinces to the north, the Eastern Province to the northeast, and the Western Province to the northwest, while being flanked by the Indian Ocean to the south (Wijeratne, 2023). Given its proximity to the equatorial belt and the presence of a monsoon climate, the region benefits from favorable climatic conditions. The Southern Province of Sri Lanka experiences a tropical monsoon climate, characterized by warm temperatures and plentiful rainfall year-round. This province is marked by high humidity and is distinguished by distinct climatic seasons. While its abundant rainfall and moderate temperatures contribute to its unique ecology, the recent impacts of climate change threaten this distinctiveness (Madarasinghe et al., 2023). The escalating effects of climate change are profoundly jeopardizing these natural treasures. Although climate patterns have historically exhibited fluctuations, the current rate of change presents an extraordinary global environmental challenge. The Southern Province of Sri Lanka has

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been facing severe extreme weather events recently, causing much economic damage. In this context, studies about the future pattern of climate change in Southern Province will help to adapt the climate change in the future.

The Southern Province is characterized by a hot and humid climate, with significant rainfall throughout the year (Alahacoon & Edirisinghe, 2021). It is imperative to conduct studies that delineate the impact of climate change in this region of Sri Lanka. Yet, there is a dearth of such studies, many of which predominantly center on water resources, while ignoring the physical, climatic, and human dimensions of southern Sri Lanka. Consequently, this study is of paramount importance, especially in crafting adaptive strategies to address current and future climate scenarios effectively. The findings of this inquiry are projected to significantly inform future developmental planning initiatives in the southern region.

RESEARCH METHODOLOGY

Study Area

The study area is situated in the southernmost region of Sri Lanka. To the north, the province is flanked by Sabaragamuwa Province and Uva Province, while to the northeast, it adjoins the Eastern Province. The Indian Ocean delineates part of its eastern and southern boundaries (Figure 1).

Climate is defined as the average amalgamation of atmospheric parameters such as temperature, precipitation, humidity, and evaporation within a specific region. This area is situated close to the equator and resides within a monsoon climate zone, characterized by its advantageous climatic conditions. The Southern Province of Sri Lanka experiences a tropical monsoon climate, noted for its warm temperatures and significant rainfall throughout the year (Alahacoon & Edirisinghe, 2021). However, two distinct seasons prevail:

- Southwest Monsoon (May to September): This period is marked by heavy rainfall, particularly in the southern coastal regions, where strong winds may occasionally lead to coastal erosion. Humidity levels remain elevated during this season.
- Northeast Monsoon (December to February): In contrast, this season witnesses comparatively less rainfall; the Northeast Monsoon tends to bring only light precipitation. Temperatures are slightly cooler in this period, interspersed with occasional dry spells.

The Southern Province exhibits a hot and humid climate, accompanied by substantial rainfall year-round. Both monsoon seasons showcase variations in rainfall patterns and temperature fluctuations. The Southwest Monsoon season, extending from May to September, also benefits from rainfall derived from the Bay of Bengal (Wijeratne, 2023). Additionally, the study area receives precipitation during the initial inter-monsoon period, from March to April, as well as the subsequent monsoon period, from October to November, attributed to pre-monsoon rainfall.

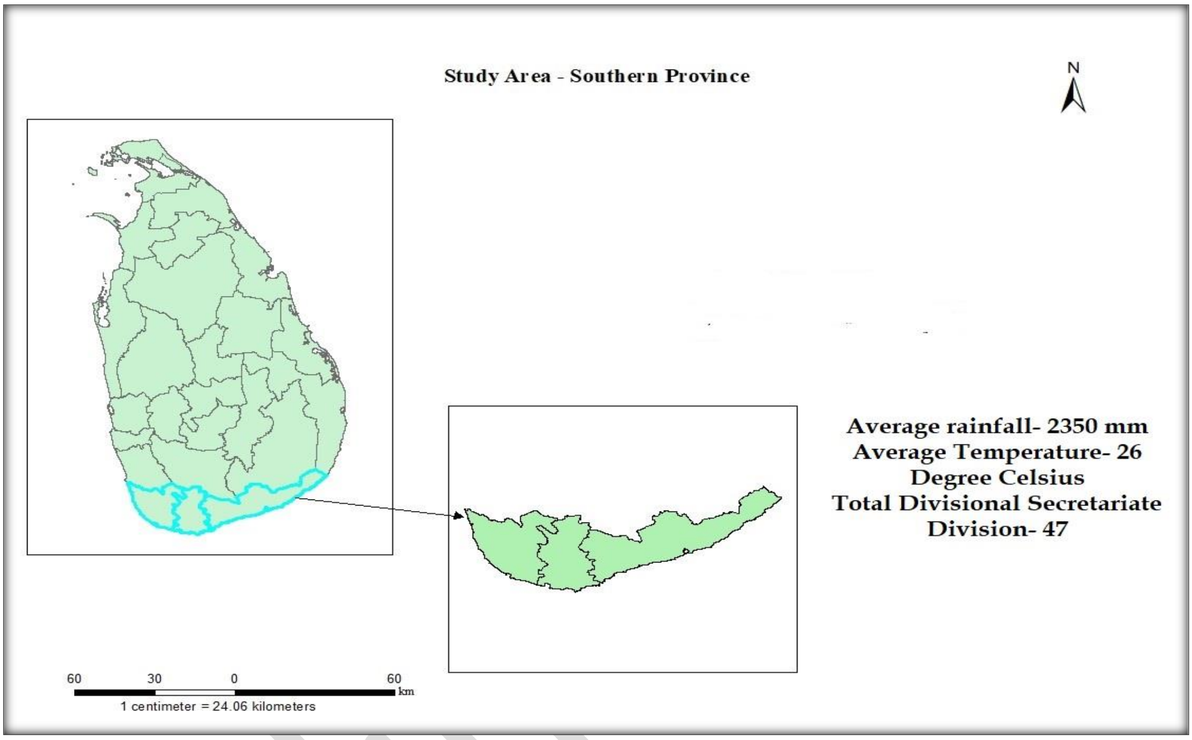

Figure 1: *Study Area (Southern Province of Sri Lanka, consisting of three districts: Galle, Matara, and Hambantota)*

This study primarily focuses on identifying projected anomalies in climate change within the specified study area. While previous research has attempted to forecast climate change in other regions, this study represents the first attempt to analyze future climate change specifically within the southern region of Sri Lanka. Future climate change data for this study was sourced from the World Bank's Climate Change Knowledge Portal (CCKP) (World Bank Group, 2021).

The academic community employs scenarios to encapsulate the spectrum of conceivable climate futures and to illustrate the ramifications of various paths, policy decisions, and technological innovations. These scenarios are framed as 'what if' propositions, selected to encompass a broad range without any affiliation to their probability. The methodology for conceptualizing various scenarios has transitioned from a climate-centric approach to one increasingly centered on societal development, offering insights into various reasonable climate consequences. Shared Socioeconomic Pathways (SSPs) are utilized in CMIP6, superseding the Representative Concentration Pathways (RCPs) introduced in CMIP5. The Shared Socioeconomic Pathways (SSPs) diverge from numerous earlier methodologies for socioeconomic scenario development in several noteworthy aspects. The developmental process seamlessly integrates both inverse and forward approaches, starting with the delineation of an outcome space that encompasses various combinations of challenges related to adaptation and mitigation. Subsequently, it identifies combinations of socioeconomic trends that are posited to lead to these outcomes (Neill et al., 2020). Socio-economic scenarios serve as a vital instrument for examining the long-term ramifications of anthropogenic climate change, as well as the array of response options available. Achieving a more coherent application of these scenarios, which would facilitate an integrated perspective on mitigation, adaptation, and the residual impacts of climate change, remains a significant challenge (Kriegler et al., 2012). Socio-economic scenarios serve as a vital instrument for examining the long-term ramifications of anthropogenic climate change and the array of available response strategies. A more coherent application of these scenarios, which would facilitate an integrated view of mitigation, adaptation, and residual climate impacts, continues to pose a significant challenge. We posit that the identification of a cohesive set of global narratives and socio-economic pathways that can be adapted to various regional contexts, encompass essential socio-economic dimensions and pertinent futures, and employ a nuanced methodology to distinguish climate policy from counterfactual "no policy" scenarios, would represent a crucial advance in addressing this challenge (Kriegler et al., 2012). In 2022, the IPCC released four representative concentration pathways; however, for this study, only SSP4.5 (medium) and SSP 8.5 (high) have been employed as a foundation for determining future temperature and precipitation variations across diverse climatic periods. Both shared socioeconomic pathways exhibit distinct carbon emission levels. Presently, Sri Lanka's carbon emissions are aligned with SSP 4.5 (Senatilleke et al., 2022). Similarly, for future estimations, SSP 5-8.5 has been applied, taking into account factors such as population growth, urbanization, and increasing transportation demands. The SSP 2.5 carbon emission level is not currently applicable. Five SSPs are delineated in CMIP6, each representing different societal developmental pathways (Arfasa et al., 2024a).

Accurate climate change predictions require substantial historical data for each climate model. The World Meteorological Organization recommends specific reference periods, such as 1971-2000, 1981-2010, and 1990-2020, for climate studies(Grigg, 2024).

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A historical simulation period is crucial to establish a baseline for each model. This study utilized the period from 1990 to 2020 as the historical baseline. Subsequent decades – 2020-2039, 2040-2059, 2060-2079, and 2080-2099 were designated as future projection periods. The analysis focused on two key parameters: mean monthly temperature and monthly precipitation. Data for this study was refined to the specific geographical coordinates of the southern region of Sri Lanka, located at 6°10'N latitude and 80°45'E longitude.

Data Validation

The validation of the methodology for future climate change data is essential to effectively utilize this information for further research within the study. To accomplish this, a comparative analysis was undertaken to evaluate the accuracy of the data. This process involved employing general circulation models to simulate historical data, which were then juxtaposed with actual observed data to ascertain their validity. In this investigation, temperature and precipitation data were generated under various scenarios by multiple models. These models provided simulations of temperature and rainfall for the study area, including ensemble data that was subsequently compared with actual observed historical records to validate the future climate change projections relevant to this study (Figures 2 and 3). Not only does a specific model suggest, but all models indicate an upward trend in future temperature and rainfall in the study area. Likewise, a minor discrepancy was noted between the historical data and the actual observed temperature and rainfall based on comparative analysis. Consequently, model-generated data for the southern province was utilized to forecast future changes in temperature and rainfall. Therefore, to assess the accuracy of the acquired future climate change data, the historical data produced by the models was compared with past observed data from the southern province. Based on this accuracy, the acquired data was employed to comprehend future climate change trends.

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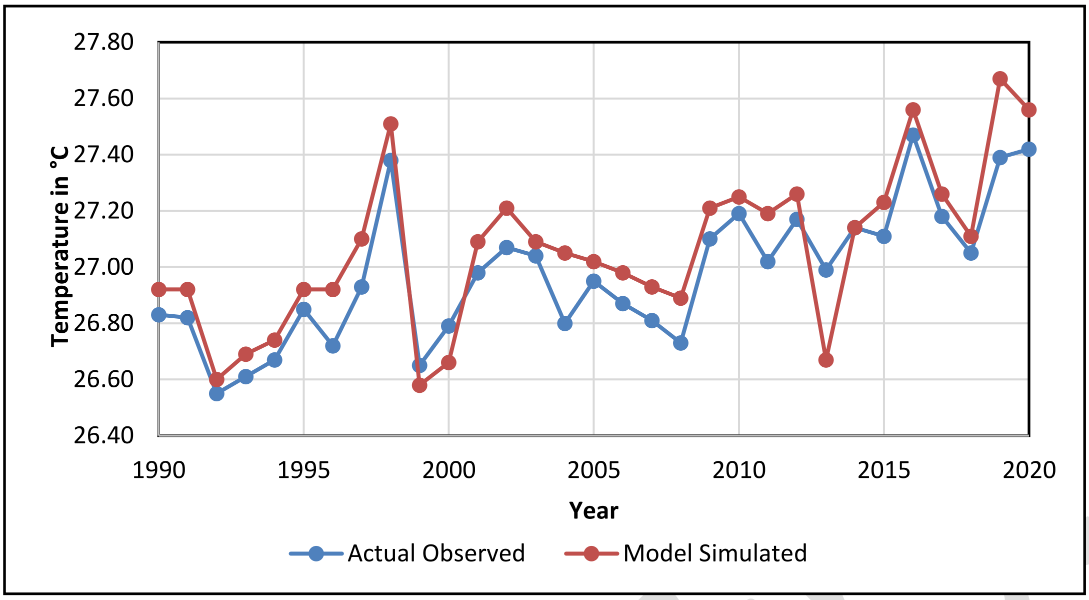

Figure 2: *Average Observed historical and Model-predicted historical temperature pattern of Southern Sri Lanka (Observed Historical data obtained from the Department of Meteorology, Colombo)*

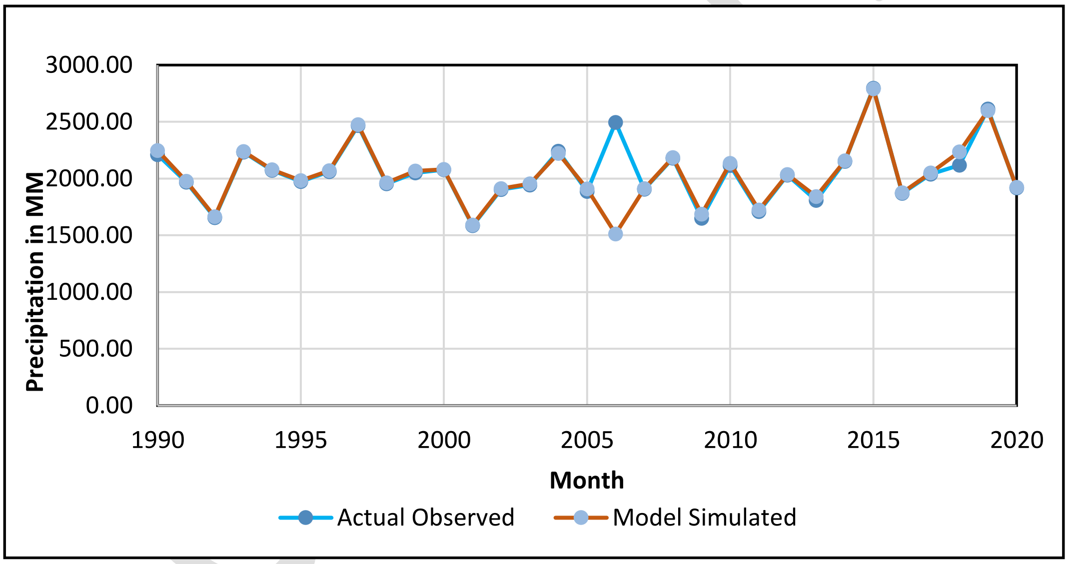

Figure 3: Comparison of Observed Historical and Model-simulated Historical Rainfall Trends of the Southern Region of Sri Lanka (Observed Historical data obtained from the Department of Meteorology, Colombo)

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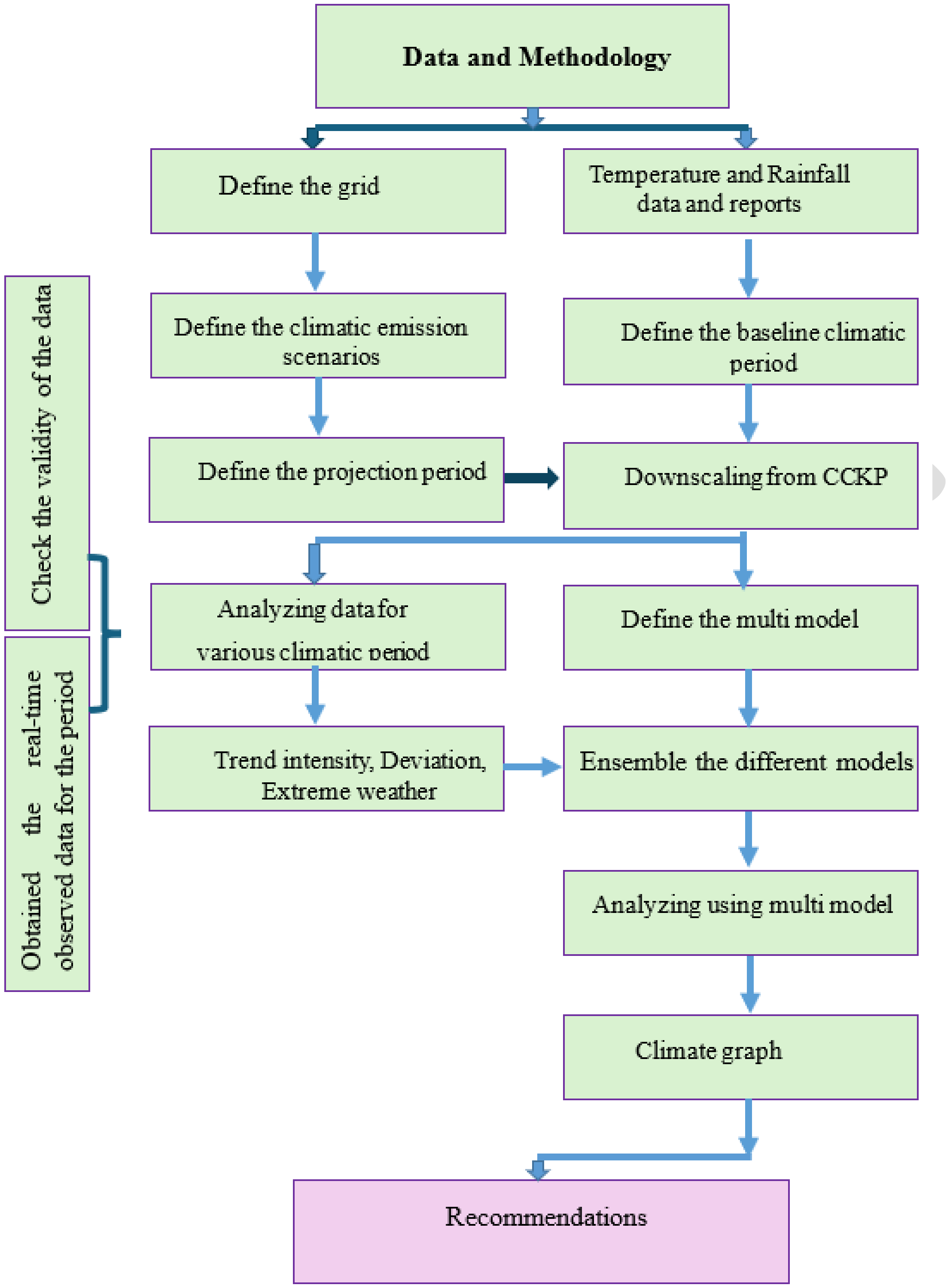

Figure 4: Methodological Flowchart of the Study

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RESULTS AND DISCUSSION

The assessment of anticipated temperature and precipitation patterns in the southern province of Sri Lanka has revealed a significant increase across various SSPs for distinct climatic epochs. Nevertheless, multimodel integrations have indicated an upward trend in both temperature and precipitation from 2020 to 2100.

Future Temperature Changes under SSP 4.5

Future temperature alterations have been scrutinized through an analysis of ten models across four distinct climatic periods, namely 2020 to 2039, 2040 to 2059, 2060 to 2079, and 2070 to 2099, culminating in the overarching period from 2020 to 2100. Temperature anomaly alterations (Mean) for the region of study have been thoroughly evaluated. Projections for the climatic period 2020 to 2100, framed within the SSP 4.5 scenario, anticipate various temperature increments in the study area. All models under SSP 4.5 uniformly indicate a rise in temperature across all climatic epochs, particularly in terms of increasing averages. The models forecast that the maximum average temperature will rise by 1.18 °C, while the minimum average temperature is expected to increase by 1.07 °C from 2020 to 2100. Based on these forecasts, May is projected to witness the most significant temperature rise in the southern region during all climatic periods, whereas October is anticipated to experience the least increase. All models within this scenario denote a temperature ascendancy across each climatic epoch.

Projected Temperature under SSP 8.5

The CMIP5 models proffer a spectrum of predictions regarding temperature changes between 2020 and 2100. Despite these discrepancies, a consensus among the models suggests an increase of 1.91°C in the average temperature of Sri Lanka's southern region over this timeframe. However, when examining the data monthly, notable discrepancies emerge. The generalized temperature projections indicate that May is expected to experience the most pronounced temperature increase, with an average rise of 2.09°C. In contrast, September and October are projected to witness the smallest increments, both anticipated to rise by 1.77°C.

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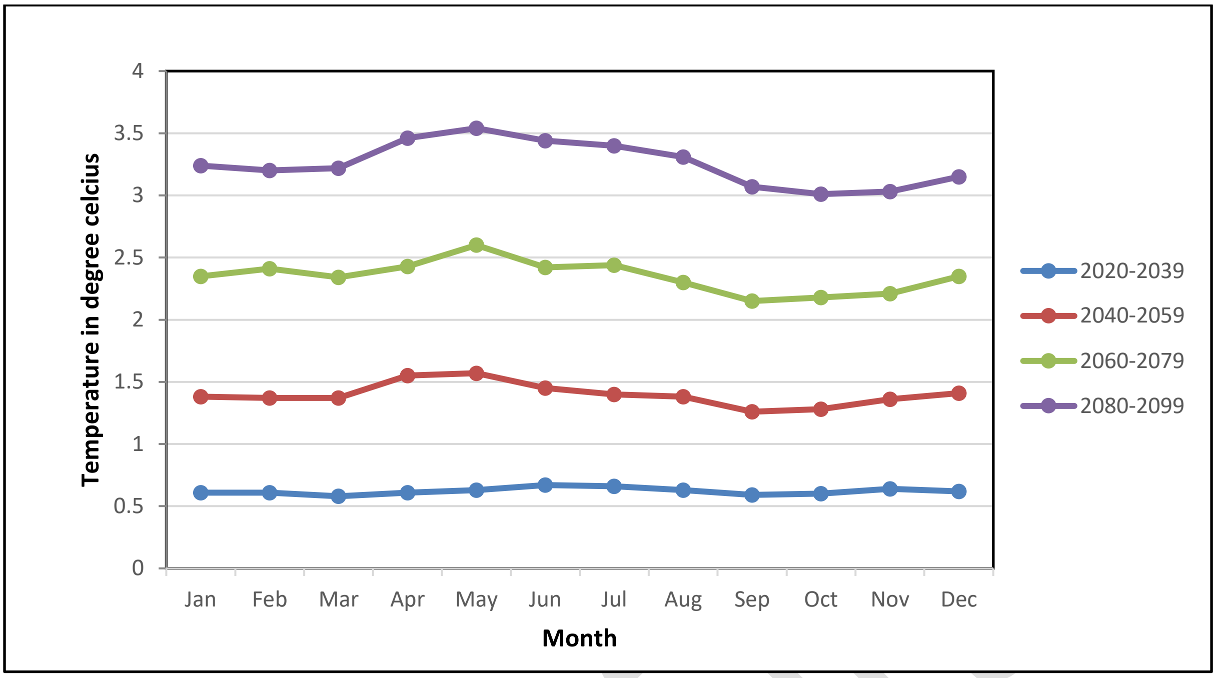

Figure 5: Predicted Monthly Temperature Variations for the Southern Sri Lankan Region under the SSP 8.5 Scenario

The analysis of each model reveals notable disparities in the average temperature increases across the various simulations. The model HADGCM3 registers the highest average temperature at 2.73°C. In close succession, the model CANESM5 exhibits a significant average of 2.63°C, while ACCESS-CM2 presents an average of 2.40°C, consistent with the projected RCP 8.5 scenario for the climate period from 2020 to 2100. Conversely, the lowest average temperature is observed in the model NORESM2-CM, which records a value of 1.41°C. Following this, the model MIROC ES-2L shows a slightly higher average of 1.45°C (see Figure 6). Model analysis indicates that October, November, and December in the Southern Province are forecasted to experience significantly colder temperatures in the future. Conversely, the months of May, June, and August are anticipated to witness elevated temperatures.

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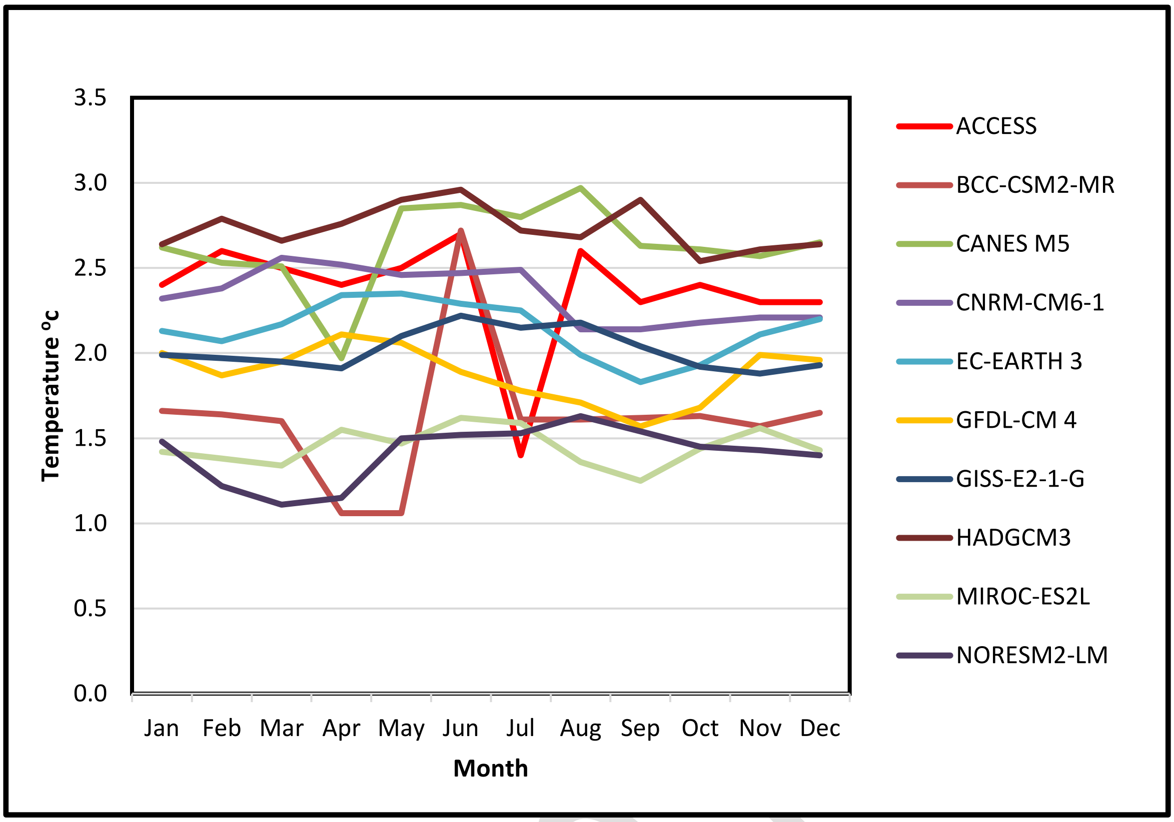

Figure 6: Various Models Projected Temperature Changes in the Southern Region (2020-2100) Under SSP 8.5

Projected Rainfall Variations of the Southern Region of Sri Lanka under SSP 4.5 Scenarios

According to the IPCC's Sixth Assessment Report on Climate Change, future alterations in precipitation have been projected based on varying Shared Socioeconomic Pathways. It is noted that annual rainfall is anticipated to rise by 122.75 mm from the year 2020 to 2100 under the SSP4.5 scenario. The most significant increase of 155.31 mm is expected in September, followed by November at 108.58 mm, while generalized models indicate a decrease in rainfall during March (-36.83 mm) and April (-15.61 mm) (Figure 7). The monthly rainfall projected by models under SSP2-4.5 is expected to diminish from January to June, with the generalized averages indicating 47.09 mm for January, 1.87 mm for February, 42.87 mm for March, 109.57 mm for April, and 104.72 mm for May. For the period spanning from 2020 to 2100, the model that predicts the highest annual rainfall increase is CANESM5, with an impressive 779.83 mm. This is followed by the NORESM2-LM model (563.6 mm) and the HADGECM3 model (460.34 mm). Conversely, the most minimal annual rainfall increase is projected by the BCC-CSM2-MR model (6.18 mm) and the GISS-E2-1-G model (62 mm). Under SSP2-4.5, the anticipated average rainfall from 2020 to 2100 reveals disparities among the models. The CANESM5 model

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forecasts a rainfall increase of 779.83 mm for the designated period, followed by ACCESS-CM2 at 262.9 mm, HADGECM3 at 460.34 mm, NORESM2-LM at 563.6 mm, and EC-EARTH3 at 211.63 mm (Figure 8).

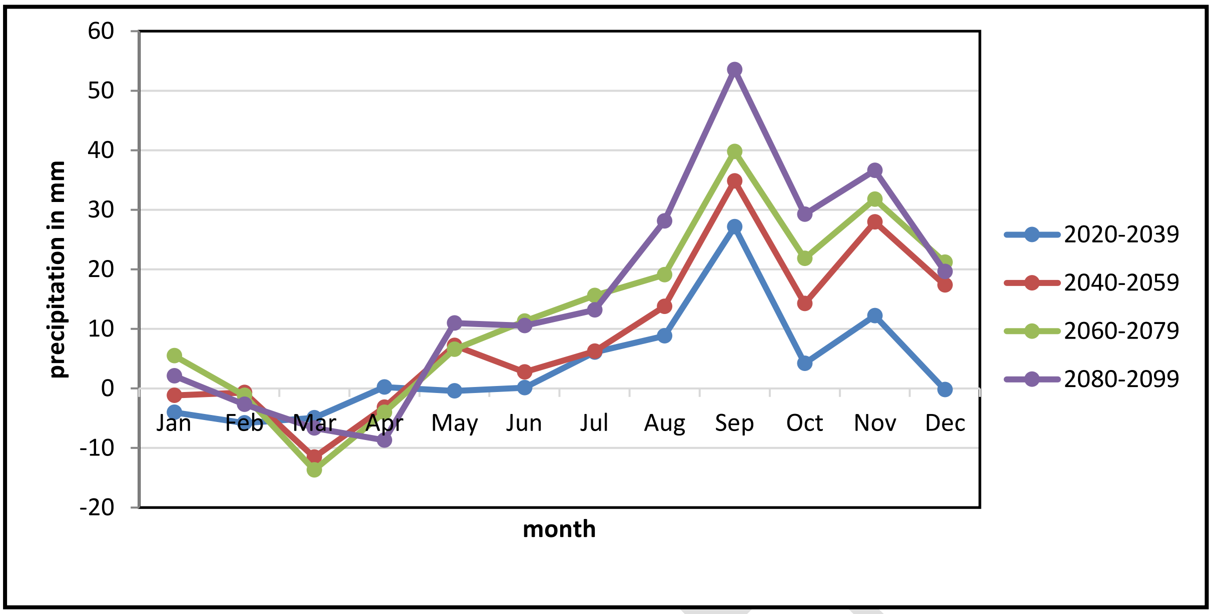

Figure 7: Predicted Ensemble Rainfall Fluctuations of Southern Sri Lanka under the Various Climatic Periods under SSP 4.5

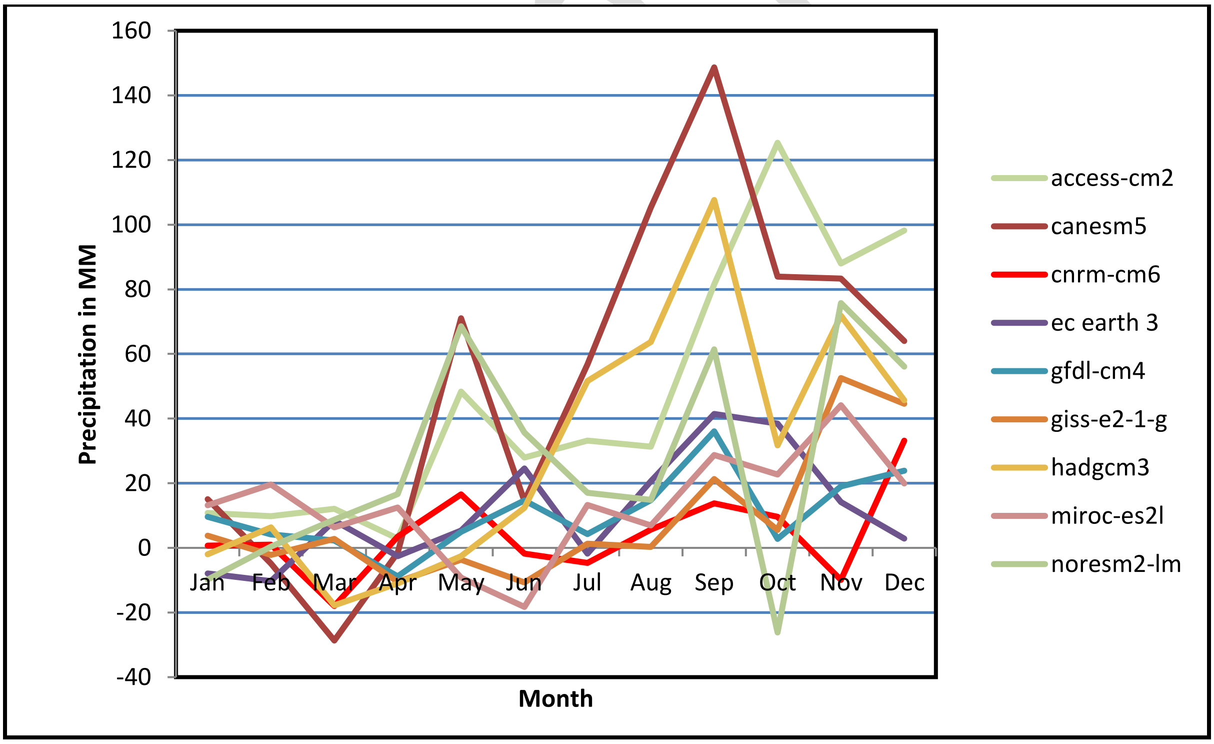

Figure 8: Models Based on Monthly Projected Rainfall Variations in Southern Sri Lanka under SSP 4.5

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Future Rainfall Changes in the Southern Region of Sri Lanka under SSP 8.5 Scenarios

All climate models uniformly predict a forthcoming rise in precipitation for the Southern Province. Although the pace of this increase will fluctuate across various seasons, an overall decrease in rainfall variability is anticipated. By the year 2100, it is projected that annual rainfall will rise by an impressive 148.47 millimeters. The most substantial increment in rainfall is expected in September, with an increase of 214.18 mm, while the least significant rise is forecasted for March, indicating a decrease of -54.67 mm (Figure 9).

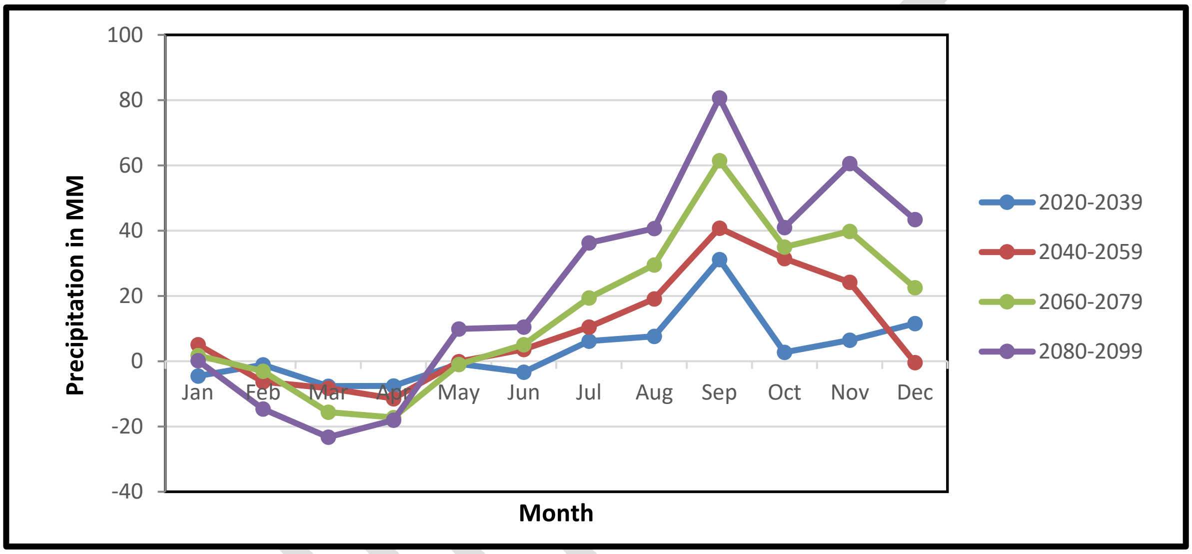

Figure 9: Models Predicted Ensemble Rainfall Variations under SSP 8.5 in Southern Sri Lanka for Different Climatic Periods

Significant disparities exist in the projected changes in rainfall from 2020 to 2100, as derived from ten distinct climate models for the southern region of Sri Lanka. This section elucidates the anticipated alterations in rainfall according to each of the ten models pertinent to this area. It is anticipated that the annual precipitation in the southern part of Sri Lanka will increase by 148.47 mm from 2020 to 2100 across all models. However, notable variances are evident in the monthly projections among these models. Under the SSP5-8.5 scenario, the models reveal a spectrum of projected rainfall changes for the specified timeframe. The CANESM5 model predicts the most substantial increase in rainfall during this period, estimating an augmentation of 725.71 mm, followed by the AACESS-CM2 model with an increase of 125.98 mm, the HADGEM3 model at 314.63 mm, the NORESM2-LM model at 444.59 mm, and the EC-EARTH3 model at 310.59 mm (see Figure 10).

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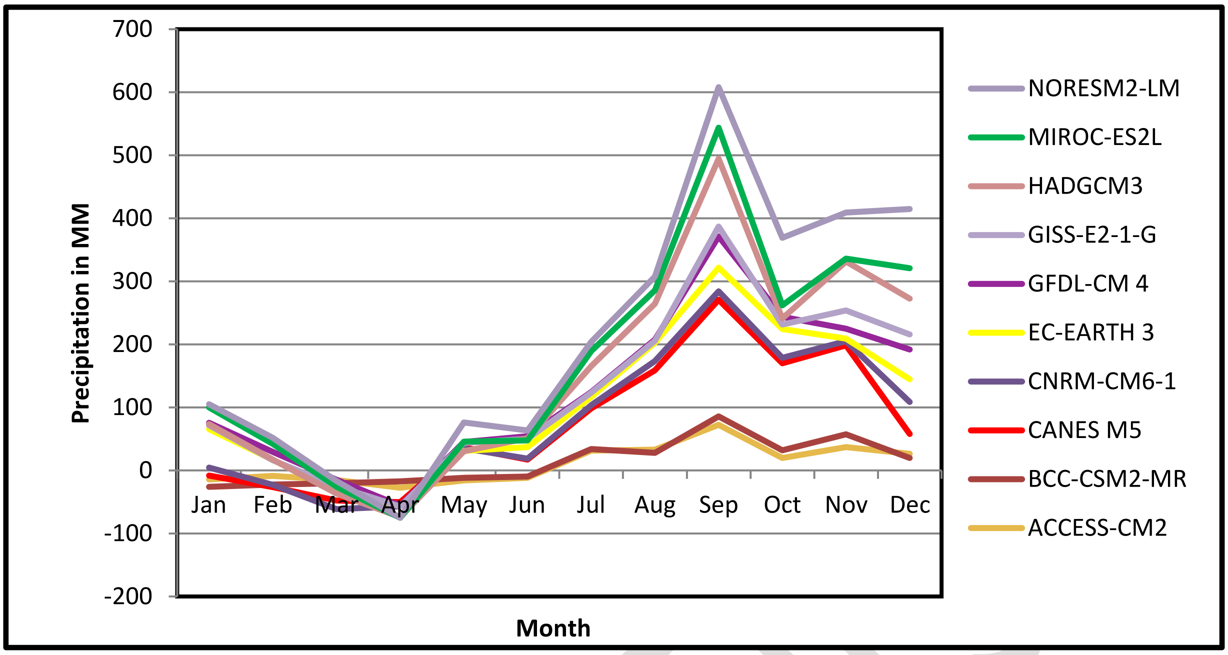

Figure 10: Models Projected Monthly Basis Rainfall Variations under SSP 8.5 from 2020 to 2100

Temperature Changes Under SSP2-4.5 Scenario

In future projections of climate change, particularly concerning rising temperatures, all models consistently depict an upward trend throughout each climate period under the SSP2-4.5 scenario. Between 2020 and 2039, May is anticipated to witness the most significant temperature increase of 0.64°C, closely followed by June at 0.63°C. The least amount of temperature increase is forecasted for September, October, and November, with an increment of 0.53°C. From 2040 to 2059, under the SSP2-4.5 model, April and May are expected to experience the highest temperature escalations at 1.09°C, while September will record the least rise at 0.91°C, per model projections. In the timeframe from 2060 to 2079, May is projected to exhibit the maximum temperature increase of 1.6°C, with October observing the smallest increase at 1.27°C, according to model predictions. From 2080 to 2099, May is anticipated to document the highest temperature increase of 1.95°C, while the minimum rise will occur in October at 1.55°C, as forecasted by the IPCC models. Collectively, throughout all climate periods under SSP2-4.5, the southern region is expected to endure the greatest temperature increases in May, while the smallest increase is projected for October. Overall, from 2020 to 2100, the average maximum temperature rise is forecasted at 1.18°C, whereas the average minimum temperature increase is estimated at 1.07°C. These findings signify a persistent temperate ascendance across all projected climate periods under SSP2-4.5.

Changes in Rainfall Under SSP2-4.5 Scenario

According to the IPCC's Sixth Assessment Report on Climate Change Impacts, anticipated variations in rainfall have been predicted based on different Shared Socioeconomic Pathways (SSPs). Under the SSP2-4.5 framework, it is foreseen that annual rainfall will increase by 122.75 mm from 2020 to 2100. In the interval from 2020 to 2039, an annual rainfall increase of 43.51 mm is projected, culminating in an average annual total of 143.23 mm. The peak rainfall is expected in November at 286.23 mm, while February is forecasted to have the least rainfall at 68.51 mm. Between 2040 and 2059, annual rainfall is expected to increase by 107.81 mm, maintaining an average of 143.23 mm. The maximum rainfall is projected to occur in November at 302 mm, followed by October at 244.52 mm, with February again anticipated to retain the lowest rainfall at 73.61 mm. During the period from 2060 to 2079, annual rainfall is forecasted to rise by 153.74 mm, with peak rainfall in November at 305.78 mm and in October at 262.11 mm. The lowest rainfall is anticipated in February at 73.15 mm. From 2080 to 2099, annual rainfall is projected to escalate by 185.96 mm, peaking in November at 310.65 mm, while February will record the least rainfall at 71.65 mm. Overall, from 2020 to 2100, the annual rainfall is expected to increase by 122.76 mm, with the maximum rise projected in September at 155.31 mm, followed by November at 108.58 mm. The minimum increases are expected in March (-36.83 mm) and April (-15.61 mm). In summary, throughout all the projected climate periods under SSP2-4.5, November is anticipated to experience the most substantial annual rainfall increase in the southern region, while February is likely to observe the least increment.

Temperature Changes Under SSP5-8.5 Scenario

Under the SSP5-8.5 scenario, the anticipated temperature rise from 2020 to 2100 varies among different models. Nonetheless, it is generally forecasted that the average temperature increment in the southern region of Sri Lanka will approximate 1.91°C during this interval. Monthly fluctuations are evident, with May predicted to display the greatest average temperature increase based on aggregated model projections. May is expected to register an average temperature rise of 2.09°C, while September and October are likely to experience the least increases, estimated at 1.77°C. From 2020 to 2039, the average temperature increment is expected to be 0.62°C, with the highest monthly increases anticipated from April to June, while September and October will continue to show the lowest average temperature rises. From 2040 to 2059, the average temperature is predicted to increase by 1.40°C. Monthly variations indicate that May will experience the highest increase at 1.57°C, while September will realize the lowest rise at 1.26°C. The most

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substantial increase is anticipated in May at 2.60°C, followed by June at 2.44°C, with September again projected to have the lowest rise at 2.15°C. From 2080 to 2099, the average temperature elevation is predicted to reach 3.26°C, with May showing the most pronounced increase at 3.54°C, while the lowest increase is expected in October at 3.01°C. In essence, under SSP5-8.5, May consistently emerges as the month with the highest temperature increase throughout all projected climate periods, while September and October continually present the lowest increases. These findings underscore significant warming trends in the southern region of Sri Lanka under the SSP5-8.5 scenario, projecting May as the month with the highest average temperature increment and October with the least, estimating a rise of 3.01°C.

Changes in Precipitation under SSP5-8.5

In general, future precipitation in the southern region is expected to rise under SSP5-8.5, with variations across different climatic periods, albeit maintaining relatively low variability overall. By the year 2100, annual precipitation is anticipated to reach 148.47 mm. Throughout the period from 2020 to 2100, the most considerable increase in precipitation is projected for September, achieving 214.18 mm, while the minimal increase is forecasted for March, indicating a decrease of -54.67 mm. During the 2020–2039 period, annual precipitation under SSP5-8.5 is expected at 143 mm, reflecting an increase of 3.39 mm compared to current levels. Monthly assessments suggest that September will experience the most significant precipitation variation with an increase of 31.17 mm, while March is foreseen to exhibit the least variation with a decrease of -7.62 mm. In the 2040–2059 period, annual precipitation is expected to increase by 108.32 mm, reaching 148.64 mm. For the subsequent 2060–2079 period, annual precipitation is projected to attain 154.41 mm, with an overall increase of 177.57 mm. November is expected to yield the peak precipitation at 313.81 mm, reflecting an increase of 39.79 mm. Similarly, September will see a substantial increase of 61.47 mm, whereas April is anticipated to have minimal change, declining by -17.24 mm. During the 2080–2099 period, annual precipitation variability is expected to reach 161.88 mm, with November expected to show the highest variability at 334.59 mm, followed by October at 281.29 mm. Conversely, February is projected to exhibit the lowest annual precipitation, with a decrease of -54.67 mm.

Significant discrepancies are noted in the average temperature increases across various climate models. The highest average temperature value is recorded in the HADGCM3 model, with an average increase of 2.73°C. Following closely, the CANESM5 shows a higher average of 2.63°C, while ACCESS-CM2 anticipates an average value of 2.40°C under the SSP8.5 scenario for the period spanning 2020 to 2100. Conversely, the lowest average temperature values are indicated in the NORESM2-CM model, with a value of 1.41°C, followed by MIROC ES2L at 1.45°C. According to model evaluations, in the future, the months of October, November, and December are projected to be the coolest in the southern region, while May, June, and August are expected to witness markedly elevated temperatures.

Projected Rainfall Patterns under SSP5-8.5 Scenario

Noteworthy differences are evident in the projected rainfall patterns under the SSP5-8.5 scenario from 2020 to 2100. This section elucidates the anticipated rainfall alterations for the southern province of Sri Lanka within the SSP5-8.5 context. Based on the aggregated average of all models from 2020 to 2100, the annual rainfall in this southern region is predicted to increase by 148.47 mm. However, remarkable monthly variations across the models are noteworthy. Under the SSP5-8.5 scenario, the model CANESM5 forecasts the most considerable annual rainfall increase, estimating 725.71 mm. Following closely, HADGCM3 predicts an increase of 314.63 mm, NORESM2-LM forecasts an increment of 444.59 mm, and EC-EARTH3 projects an increase of 310.59 mm. Additionally, MIROC ES2L anticipates the least increase, projecting 241.45 mm.

Significant variations in projected rainfall patterns are also apparent under the SSP2-4.5 scenario from 2020 to 2100. This section details the anticipated rainfall changes for the southern province of Sri Lanka under the SSP2-4.5 framework. According to the collective average of all models, an increase in annual rainfall is expected in the southern region, although notable monthly variations are observed. From January to June, monthly rainfall is projected to diminish: January at 47.09 mm, February at 1.87 mm, March at -42.87 mm, and April at -109.57 mm. Over the period from 2020 to 2100, the highest annual rainfall increase is projected by CANESM5 at 779.83 mm, followed by NORESM2-LM at 563.6 mm and HADGCM3 at 460.34 mm. Conversely, the lowest increases in annual rainfall are anticipated from BCC-CSM2-MR at 6.18 mm and GISS-E2-1-G at 62 mm. These findings illuminate considerable disparities in rainfall projections across various models and scenarios, underscoring the necessity for region-specific climate adaptation strategies.

CONCLUSION

Climate change has emerged as one of the most formidable threats confronting the world today, evolving into a global challenge that presents diverse hazards to nations across the globe. This urgent issue is precipitating a myriad of political, economic, social, and international relational dilemmas. In this context, there exists a notable

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paucity of research concerning climate change awareness among the populace of Sri Lanka, particularly in terms of future climate scenarios. Additionally, region-specific studies remain severely limited. The objective of this research is to scrutinize the anticipated climate change in Sri Lanka's Southern Province under various prospective scenarios. By exploring the future climatic alterations in the Southern Province, this study aspires to inform policy formulation and foster sustainable practices to alleviate potential impacts.

This investigation has unveiled an upward trajectory in projected temperature and precipitation patterns across different future climate scenarios in Sri Lanka's Southern Province, with the SSP scenarios. Utilizing a multi-model ensemble approach, a range of temperature and precipitation variations has been elucidated. From 2020 to 2100, disparate models have indicated varying results. According to this analysis, under the SSP2-4.5 scenario, the temperature is expected to rise by 1.18 °C, accompanied by an increase in precipitation of 122.76 mm. Under the SSP5-8.5 scenario, the temperature may rise by 1.91°C, while precipitation could increase by 148.47 mm. Given that temperature is a fundamental climatic variable, its elevation will undoubtedly affect the climatic conditions as well as the physical, economic, and social structures of the region. Furthermore, the likelihood of extreme weather events is anticipated to increase.

The advocacy for sustainable development in the Southern Province is of utmost significance. In this regard, this study helps and is an important source for the identification of the projected climate change in different SSPs under different climatic periods using various models. Further, this study will be the source for the future development plans of the Southern Province of Sri Lanka, encountering future impacts of Climate change. Even though there are some limitations, such as the inability to identify the spatial pattern of changes in the future climate change in the Southern Province of Sri Lanka

In light of its susceptibility to the repercussions of future climate change, it is imperative to adopt measures aimed at mitigating these effects. Prioritizing strategies to curtail carbon emissions and bolster climate resilience is essential. By concentrating on sustainable agricultural methodologies, effective water resource management, infrastructural development, and the conservation of coastal ecosystems, the adverse effects of climate change on the region can be substantially diminished. Moreover, fostering individual and communal awareness is recognized as one of the most efficacious approaches to combat climate change. As personal awareness can proliferate into the collective consciousness at the community, regional, and national levels,

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coordinated efforts to address climate change can markedly lessen our overall ecological footprint.

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